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PUBLIC HEALTH IMPORTANCE OF WATER SUPPLY AND WASTE DISPOSAL WORKS

by Daniel A. Okun

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PUBLIC HEALTH IMPORTANCE OF WATER SUPPLY AND WASTE DISPOSAL WORKS

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The sanitary engineer engaged in control of the evvironment for the promotion of health is today involved in many diverse activites. In addition to the time-honored responsibilities of providing an adequate, safe water supply and satisfactory disposal of human wastes, he now finds himself concerned with control of many other facets of our enviroment that affect health: the air, milk and food, occupational hazards, mosquitoes and flies, rodents, bathing areas, home accidents, industrial wastes, etc.

Civil engineers who turn to sanitary engineering, however, are generally occupied in the investigation, design, construction and operation of water supply and waste disposal projects, and for this reason, this paper will concern itself primarily with the health implications of such projects.

Forty years ago, it would perhaps not have been necessary to elaborate on the value to the public health of a safe water supply. Installation in 1912 of a plant for the filtration and chlorination of Niagara River water for the City of Niagara Falls, where the typhoid fever death rate from 1900-1911 had been 131.8 per 100,000, effected a 90 per cent decrease in the death toll over the next twelve years (1). A new water supply project in the United States today will exhibit no similar handsome reward. Nor will the vital statistics record significant achievement upon completion of a multi-million dollar sewage disposal works.

The typhoid death rate has always been considered to be an accurate barometer of sanitary status. Figure 1 indicates how typhoid deaths from all causes have dropped to less than 1 per million in urban populations in the last seventy years. The qualitative change that has taken place may be better appreciated if it is realized that at the turn of the century a student at a large university could expect to see several of his classmates die of typhoid during his four-year period of study. Now the rate is so low that a death from typhoid would hardly be expected to occur in a student body once in two hundred years.

The situation is similar with regard to other water-borne diseases. Among the leading causes of death in the United States in 1949, those which might be attributed in some number, however small, to organisms which could be water-borne rank as follows:

Rank	Disease	Deaths
15th	Gastritis, enteritis, etc.	9970
32nd	Dysentery	1440
38th	Typhoid	161
----	Cholera	0

It is interesting to note that "Suicide" was listed ahead of all of these, 12th in the list of most important causes of death, with "Homicide" 18th. Reference to these products of social and mental disease will be made later in the paper.

With water-borne disease already at low levels how can we evaluate the importance to the public health of water supply and waste disposal works? Can such projects, expensive as they are, be economically justified? Are there further horizons of public health to be achieved by the civil engineer who engages in sanitary engineering work?

For those engineers who seek employment, opportunity and adventure in some more primitive foreign lands, the dramatic reduction in illness and death will still reward their activities.

It will be the purpose of this paper, however, to indicate some of the problems still to be solved in the promotion of the public health through water supply and waste disposal projects in the United States. These problems will be classified into three groups: (1) Elimination of Communicable Disease; (2) Control of Toxic Compounds; and (3) Promotion of Well-being.

Control of Communicable Disease

The important communicable diseases, the causative organisms of which are transmittible in water, are typhoid, cholera (none in U. S.), amebic and bacillary dysentery, and gastroenteritis. Gastroenteritis is a catch-all classification which includes those enteric diseases for which no specific organism can be held responsible. Frequently failure to make laboratory diagnosis in a gastrointestinal case will result in its being labelled gastroenteritis rather than a specific disease. Whether or not the organism is found, however, diseases can be charged to water supplies when epidemiological investigation reveals a pattern of infection for which only water can reasonably be held guilty, and when contamination of the supply is indicated.

The prevalence of water-borne disease can, therefore, only be estimated. The reporting of water-borne disease outbreaks may reflect more the diligence and ability of the responsible health authority in recognizing an outbreak and tracing its cause than the actual prevalence of the disease. Many mild cases do not even come to the attention of the family physician, and many minor outbreaks are missed by health authorities.

Typhoid

Of the water-borne diseases, only typhoid can be considered to be reported with any degree of accuracy. Figure 2 shows the number of cases of typhoid associated with water-borne outbreaks since 1920. Control measures, particularly the program instituted in many states for the registration of typhoid carriers, have made feasible the virtual elimination in the U. S. of this formerly dreaded disease. Examination of the causes of the water-borne typhoid outbreaks that have occurred may give a clue to their elimination. These causes have been summarized in the literature by Gorman and Wolman. for 1920-1936 (2) and by Eliassen and Cummings for 1938-1945 (3). The classification of causes is according to that set up by Gorman and Wolman The data for 1946 through 1951 are from the Public Health Service (4), and for 1952 from the Weekly Reports of the National Office of Vital Statistics (5). The breakdown into classifications of the 1946-1952 data are by the author.

FIGURE 1

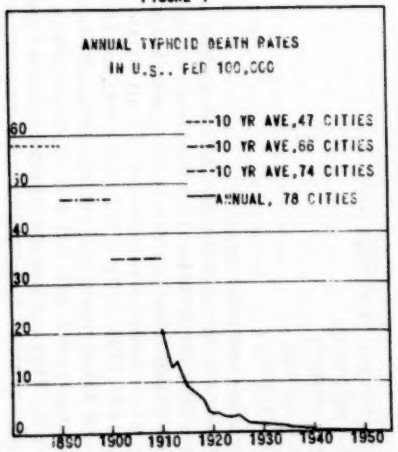


FIGURE 2

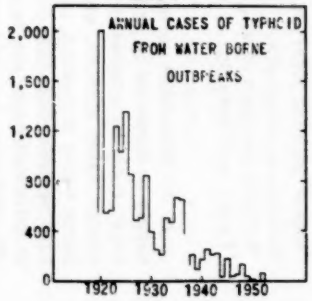


FIGURE 3

CASES OF TYPHOID FROM WATER BORNE OUTBREAKS ACCORDING TO SOURCE OF WATER

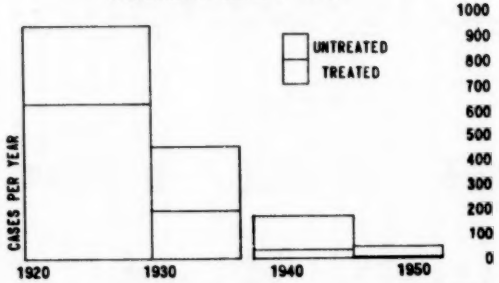
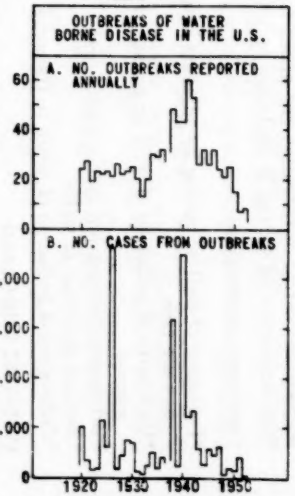


FIGURE 4



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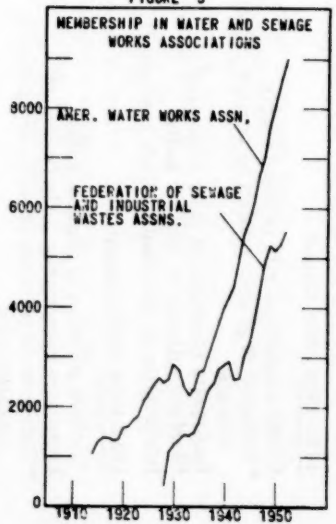

Table 1

LEADING CAUSES OF TYPHOID FEVER IN WATER BORNE OUTBREAKS

Cause	Cases	Percent of Total
1920-1929 (9421 Cases)		
Cross-connection with polluted supply	1990	21
* Pollution of gravity conduit by surface water or sewage	1814	19
Inadequate chlorination (only treatment)	1063	11
*Surface pollution of shallow wells	660	7
Interruption of chlorination (only treatment)	594	6
1930-1936 (3164 Cases)		
*Surface pollution of shallow wells	501	16
Inadequate chlorination (only treatment)	355	11
*Underground pollution of wells or springs in fissured rock	344	11
Inadequate control of filtration and allied treatment	253	8
*Contamination of spring by pollution on watershed	183	6
1938-1945 (1359 Cases)		
*Pollution of well or spring by adjacent sewer or sewage tank	332	24
*Underground pollution of well or spring by unkown source	226	17
Inadequate chlorination (other treatment)	106	8
*Surface pollution of wells	99	7
*Underground pollution of wells in fissured rock	83	6
1946-1952 (332 Cases)		
*Pollution of well from adjacent sewer or sewage tank	113	34
*Use of polluted river water - untreated	106	32
Inadequate chlorination (only treatment)	37	11
*Surface pollution of wells and springs	23	7
*Faulty well covering or construction	5	2

* Signifies untreated supply.

In the 1920-1929 period, failure on the part of operators of public water supply systems led in responsibility for typhoid. In subsequent years, fewer cases could be attributed to operating failure, and a greater percentage to contaminated sources, where no treatment was provided. Of all water-borne cases of typhoid, in the 1920-1929, 1930-1936, 1938-1945, and 1946-1952 periods, 33%, 57%, 79%, and 82% of cases respectively were attributable to untreated supplies, or conversely, 67%, 43%, 21% and 18% to supplies afforded some type of treatment. This is illustrated graphically in Figure 3.

From these data it would appear that a long step towards elimination of water supply as a source of typhoid would be treatment, at least disinfection, for all municipal, camp, institutional and similar supplies.

Gastroenteritis

A program of disinfection for all supplies would not only reduce the

typhoid rate, but would have a salutary effect on the incidence of all other water-borne diseases. Data on the incidence of these other diseases are not reliable, but for each case of water-borne typhoid there have been from 10 to 100 cases of water-borne gastroenteritis reported in the U. S. Figure 4 indicates the incidence of reported water-borne outbreaks and cases. The data for this figure were obtained from Gorman and Wolman (2), Dauer (6), and the 1952 Morbidity and Mortality Reports issued by the National Office of Vital Statistics (5).

Figure 4 also illustrates the most important health aspect of public water supplies -- the wholesale infections that can occur when proper operation of the water supply works or the necessary vigilance in their protection are not maintained. Of the 46,000 cases of water-borne diseases reported in 1926 from 21 outbreaks, some 45,000 were from a single outbreak in Detroit, Michigan due to inadequate treatment. Of the 31,700 cases of water-borne diseases reported in 1938 from 48 outbreaks, almost 30,000 were from a single outbreak alone in Milwaukee, Wisconsin. Gorman and Wolman state that"..... there is strong presumptive evidence that contaminated water, not treated with sufficient chlorine, may have been the cause ...." Since that time, when chlorination was the only treatment at Milwaukee, filtration facilities have been installed.

Of the 44,200 cases shown in 1940, from 43 outbreaks, some 35,000 were from one outbreak in Rochester, N. Y. This outbreak resulted from a cross-connection between the potable water supply and a polluted river supply used for fire protection. A valve between the two systems was accidentally left open.

The early history of water supply is replete with examples of the toll taken by single outbreaks. In their notable report on water-borne outbreaks in the 1920-1936 period, Gorman and Wolman concluded that"One of the most distressing aspects.....was the number (of outbreaks) due to apparent laxity in operation of water purification plants or equipment for chlorination of public water supplies. There is clear evidence that more strict supervision and control over water treatment processes by public health and water works officials are urgently needed."

That this closer supervision has been attained is attested to by the morbidity data in Figure 4, and by the analysis of causes of typhoid over the years. Failures in performance of operating personnel are now rare. This has been achieved by the training of water works personnel initiated and carried out by state departments of health, by the water and sewage works associations, and by universities. In 1947 alone, 2422 students were trained in 24 short courses in 16 states. (7). Some measure of the increase in qualified personnel available to operate our water and sewage works may be seen in Figure 5. In the nine years 1943 to 1952, the American Water Works Association membership grew more than it had the previous 30 years.

Amebiasis

However, the battle for vigilance does not stay won. Except perhaps for typhoid, we may, for many years to come, expect to have a reservoir of infection in our populations that can result in explosive outbreaks of disease.

From 5 to 10 percent of our population harbor the parasite Entamoeba histolytica, the causative organism of amebiasis (amebic dysentery). While a large degree of contamination is necessary for infection, it must also be kept in mind that ordinary chlorination practice is not sufficient treatment to destroy the cysts of E. histolytica.

Only three outbreaks, although many cases, have been traced to water. The 1933 "hotel" outbreak in Chicago was most disastrous (8). More than 1400 cases of amebiasis with 98 deaths resulted from probable sewage leakage into a cooling tank for drinking water in a hotel. In the second, at a stockyards fire, fireman and others drank from hydrants supplied with sewage-polluted water. The third occurred in Tokyo in 1947 (9, 10). Because of the mildness of this latter outbreak, it probably would have been passed off as "gastroenteritis" except for the fact that all the Americans affected were under military control. This outbreak was attributed to overflow of a sewage tank in the basement of an apartment house, submerging a water line subject to negative pressure. Many other outbreaks of amebiasis are probably classified as "gastroenteritis."

Cholera

Cholera is a disease which has disappeared in the U. S. It had also virtually disappeared in Egypt in 1903. Except for 5 cases in 1918, there had been none in Egypt until the disease was reintroduced in 1947. In a month, there were more than 8300 cases and 3200 deaths reported. In all before the end of the epidemic, more than 10,000 had died. Polluted wells in addition to other modes of transmission played an important part in the spread of the disease (11).

There is little likelihood that cholera will appear in the U. S. But its prevalence in other parts of the world, the fact that the cholera vibrio may multiply in sterile river water and in well water, and the absence of natural immunity to the disease, dictate that our water treatment guards must not be relaxed. The standard water purification procedures are adequate to destroy the organism.

Infectious Hepatitis

Infectious hepatitis is a relatively widespread disease often only recognized when manifested by jaundice. While relatively mild, it was pandemic during World War II. It is caused by a virus transmitted by the fecal-oral route, most generally through person-to-person contact under insanitary conditions. It is largely a disease of childhood and adolescence, when the disease is mild and not often accompanied by the characteristic jaundice. Infection at early age is believed to confer a permanent immunity.

Because the presence of the infectious agent - the virus - can only be detected by inoculation of a human volunteer, many cases probably go undetected. However, a recent explosive water-borne outbreak was reported by Neefe and Stokes (12). In a population of 573 in a camp, 350 cases developed, 255 with jaundice. Investigation of this epidemic revealed conclusively that the source of the bulk of the infections was an untreated well supply. Cesspools some 100 feet distant in hardpan and limestone were the points of origin of the virus. This investigation provided the first experimental evidence concerning a mode of transmission of infectious hepatitis and was the first evidence of a water-borne virus causing disease.

As our environment becomes more sanitary and children become protected from early infection, there is less likely to be immunity in the population, laying it open more easily to infectious hepatitis, and the disease is likely to be of a more serious nature. Some concern is naturally to be expected concerning the resistance of the virus to standard water treatment processes.

Experimental work on this virus is necessarily difficult because of the

need for demonstrating the presence of a single organism by the infection of a human volunteer. However, investigation by Neefe, et al (13) did indicate that treatment of contaminated water to a chlorine residual of one ppm for 30 minutes did not inactivate or attenuate the virus. A dose of 15 ppm for 30 minutes, much heavier than usually applied to water supplies, did result in attenuation. Treatment with soda ash, alum and activated carbon did not completely remove or inactivate the agent. The virus is unusually hardy. Heating to 56°C. (which destroys E. typhosa) does not prevent pathogenicity of the virus (4). It is characteristic of the causative organisms of other environmental diseases in that it can survive outside the body.

As our diagnostic procedures improve, and recognition of the disease is rendered less difficult, we will find that many outbreaks, which formerly would have been classified as "gastroenteritis," will now be identified as infectious hepatitis. The increasing importance of this disease is vouchsafed by the fact that for the first time in 1952 this disease has been made "reportable" by the States to the Public Health Service. In the first nine months of 1952, when reporting can still be expected to be weak, some 12,000 cases were reported. Two epidemic outbreaks were reported where water was believed to be the vehicle of infection (15).

Poliomyelitis

Poliomyelitis is also a virus disease. The polio virus, one of the more resistant of human viruses, is known to be present in the throat and intestines of overt and "silent" (nonparalytic) cases and to be discharged with oropharyngeal secretions and fecal excretions. The virus survives weeks at ordinary temperatures and months in the refrigerator, always retaining its capacity to infect monkeys.

The virus has been repeatedly demonstrated to be present in sewage from an infected community during epidemics. It has been present in such numbers that it had been believed to multiply in sewage. A more reasonable explanation is that the amount of virus in sewage is a true reflection of the incidence of infection in a community, which includes about 100 nonparalytic infections for each paralysis case.

Gear (16) reports that the virus has been found in sewage from a community five weeks before the first case was diagnosed, and 8 weeks after the last paralytic case was removed from the area. During suceeding months of a non-epidemic year, no virus was found.

It may be worthwhile to divert and discuss the fate of the polio virus in sewage treatment and water treatment processes as reviewed by Gear. Plain settling and trickling filtration will not inactivate or remove the virus. Activated sludge treatment and sand filtration will. Raw sludge from virus-laden sewage will generally contain the virus, but well digested sludge does not indicate its presence. Effluent from a septic tank contained the active virus two months after the last case had been removed. Standard water purification practices, particularly with disinfection by free residual chlorine, are reported to inactivate the virus, although all observers are not in agreement.

However, although the virus has been found to be present in sewage effluents, and it is theoretically possible for it to be passed on into a water supply, attempts to recover the virus from water supplies have not been successful. On the basis of the large number of epidemiological investigations made during the last half-century, Maxcy (17) concludes that there is "...no instance on record up to the present in which convincing evidence has

been presented that pollution of a community water supply was responsible for...widespread exposure of consumers to infection with the virus."

One outbreak in Connecticut in the summer of 1939 (18) was reported to have a distribution of cases that appeared to involve the Naugutuck River, a highly polluted stream. But there was no conclusive proof that water was the vector. In Sweden, considerable credence has been given to the water-borne hypothesis - but here also, definitive evidence is lacking. While water has not been convicted, neither has any other mode of transmission, although epidemiologists consider person to person contact to be the most probable mode for most cases.

We are faced in poliomyelitis with an anomoly for sanitarians. Polio had been termed "infantile paralysis" but we note an increasing number of adult involvements. Modern sanitation has greatly diminished the probability that an infant will be infected with the virus. In the absence of early immunizing infections, sanitary communities are more liable to epidemics. Contrariwise, in primitive, insanitary communities, the disease is apt to be endemic, so that members of the community are infected and immunized early in life. As in the case of the other virus diseases, measles and infectious hepatitis, the disease is less likely to be serious in the young, often resulting in subclinical infections. In the adult, these diseases are more often quite serious. So an increasing severity in paralytic cases may be the price of sanitation!

Other Infectious Diseases Associated with Water

Other infectious diseases that are, or may possible be transmittible through water are schistosomiasis, tularemia, and tuberculosis.

It has been estimated that more than 90,000,000 people over the world are infected by blood flukes, the causative parasite of schistosomiasis (19). The severity ranges from mild, often unrecognized cases, to heavy infections causing death. Eggs of the schistosome are discharged in feces or urine. They go through a larval stage in intermediate host snails which are present in receiving waters. Cercariae leave the snail and attack the human host through the skin when it is in contact with contaminated water. Thus far there have been no proven cases originating in the United States, although suitable host snails have been found.

A schistosome dermatitis caused by non-human cercariae, particularly those of birds, has been troublesome in the north central lake areas, particularly in Wisconsin and Michigan. Many swimming and resort areas have been seriously affected. Several methods of control have been tried, including abstention. The most promising control measure has been destruction of the host snail. In 1939, the Michigan Stream Control Commission organized a Division of Water Itch Control, which used annually 20 tons of copper sulfate and copper carbonate for the destruction of snails. There have been no serious outbreaks since 1943 (20).

Tularemia is an infectious disease of wild rodents, particularly rabbits, caused by Pasteurella tularensis, so named from its initial discovery in Tulare County, California. It had been of great interest because of its relatively high mortality rate, about 7.4%. Tularemia is contracted through every avenue of infection, but only two outbreaks have been reported to be water-borne. One outbreak of 43 cases in the Soviet Union (21) and one outbreak with 4 cases plus 4 additional subclinical, but infected cases in Montana (22). In each instance, the water supply was found to be contaminated with the causative bacterium, P. tularensis.

The possibility of transmission of tuberculosis through sewage and water is at this time only academic, with its widespread transmission by other means. Tubercle bacilli have been found in the raw sewage and septic tank effluent from tuberculosis sanatoria, and cattle grazing in the vicinity have been reported to have contracted tuberculosis (23). The consumption of unpasteurized milk from tuberculous cows might initiate tuberculosis infection via the alimentary tract. The chain of circumstances is too remote, however, to warrant much consideration.

Control of Toxic Compounds

Virtually all chemical compounds may be considered to be toxic, if ingested in sufficient quantity. The determination of safe limits for chemicals in water is a difficult problem because of the physiological variation between different groups of people - children as against adults for example. Also, some compounds may be readily eliminated from the human body, and only highly intense doses could cause harm. Some occasional physiological malfunction could effect the elimination processes of individuals with resultant damage. Other compounds tend to accumulate in the body and limits of concentration have to take into consideration the duration of exposure as well as intensity. Many toxic effects may be mild and insidious in character, difficult to recognize or diagnose.

Water is nature's most important solvent. Between the formation of the drop of rain and its ingestion as drinking water there is ample opportunity for the water in its travels over and through the earth to dissolve innumerable naturally occurring compounds. It has been estimated that 5 billion tons of earth salts are dissolved in river water annually (24). In addition, with the growth and intensification of industry, water is exposed to many man-made compounds, the effect of which on the human system we know very little. We know nothing of the synergistic action of these chemicals. Hollis (25) has pointed out that, at the Cincinnati Environmental Health Center, a variety of complex organic chemical compounds have been extracted from city water supplies. Some were traced to outfalls more than 300 miles upstream. The increased use of radioactive materials will result in an increased level of radioactivity in water courses and water supplies. New industries are today being planned, wastes from which are an unknown quantity insofar as public health is concerned.

In this section, the problems of those toxic compounds present in waters or wastes which have already indicated that they do or may have an effect on health will be discussed.

Flurorosis

Much public attention has been devoted to the addition of fluorine compounds to water for the purpose of reducing the caries incidence in teeth. This will be discussed later in the paper. The problem of excess natural fluorine in water has a somewhat older history. Water with a fluoride content in excess of 1.5 ppm has been demonstrated to cause fluorosis, or mottling of the teeth, among some consumers. The extent and severity of this disease varies with the concentration of fluoride and susceptibility of the individual. In some instances, the mottling is severe. In one of the early investigations in 1935, it was found on examination of the teeth of residents in West Texas and in the Texas Panhandle, that of 53 communities in 37 counties examined only six communities were negative or borderline com-

munities with respect to fluorosis (26). In all the U. S., it has been estimated that more than 1,500,000 people are now constrained to using waters containing excessive fluorides (27).

The engineering problems involved in fluoride removal have not been solved, if the term "solution" is considered to imply reasonable economy. Methods for removal of fluorides are available. Two contact filter installations, one using tricalcium phosphate (28) and the other, activated alumina (29), are believed to be the only two operating plants in the country in the more than 500 communities which need such installations. These filters have to be regenerated with caustic soda and then neutralized with weak acid. The chemical costs for these units are more than ten-fold greater than average chemical costs for ordinary water purification. Much needs to be done in this field, especially for the many small communities that are using well water high in fluorides.

Metals, Metal Salts and Miscellaneous Poisons

Many of the metals and their salts are or may possibly be of concern to the public health. There has been considerable uncertainty in evaluating the importance and the toxic limits of some of these, although studies are being made. For example, the 1925 Treasury (Public Health Service) drinking water standards placed a strict limit of 0.2 ppm on the copper concentration of potable waters. Since then it has been determined that body requirements of copper are at least 2 mg per day and most diets contain 2-4 mg each day. At a water consumption of 1.5 liters per day, water with 0.2 ppm of copper would provide only 15% of the body requirements. The 1946 Public Health Service standards (30) have raised the limit to a suggested 3.0 ppm.

Similarly, the 1925 limit for zinc was 5 ppm. Physiological investigations reported by Negus (31) revealed that 40 ppm were not harmful. The suggested limit in the 1946 standards is 15 ppm. As is the case with many potentially poisonous compounds, water with copper or zinc in significant concentrations will prove distasteful before being toxic.

In the 1946 standards, the only chemicals for which exceeding the limits "shall constitute grounds for rejection" are lead, fluoride, arsenic, selenium and hexavalent chromium.

Plumbism, lead poisoning, is no longer of great significance in connection with water supply, although lead is a metal which the body generally eliminates at a low rate. The danger of ingestion of lead from water supplies has been eliminated to a considerable extent by reducing the aggressiveness of soft waters and by increased use of copper services. Arsenic is of little importance in water supplies although Muehlberger (32), in his survey, reports 500 cases of poisoning in Manchester, England were traced to beer containing 2-4 ppm of arsenic. A source of lead and arsenic today is in waters draining regions heavily sprayed with lead arsenate. Fairhall (33) reports, however, that even in one of the most heavily sprayed areas in the U. S., Wenatchee, Washington, where 7 million pounds of lead arsenate are sprayed annually, there was little effect on local water supplies.

Selenium is rarely found in U. S. waters although there have been reports that highly seleniferous forage has killed cattle (31). The minimum lethal dose has been estimated to be 2-4 mg per pound of body weight (34). Selenium has been shown to be of relatively little importance in waters.

Chromium, in its hexavalent form, which includes chromic acid and its chromate salts, is extremely poisonous. There are increasing amounts being discharged into sewage treatment plants and directly into streams from the chrome plating industry. There are no quantitative data available on its toxi-

city to humans. Investigations on dogs indicated that daily doses of 1.2 - 2.0 mg of potassium bichromate per kilogram of body weight caused death. Muehlberger (32) reports that a plating waste discharged to a gravel pit in a limestone area contaminated 6 wells 1000 feet distant, to the extent that the water in these wells showed 11 ppm of chromium. If the data on dogs are extrapolated, this amount might be considered toxic to small children. Davids and Lieber (35) reported that in Nassau County on Long Island, industrial pollution of the ground water resulted in contamination of many well waters to the extent that they contained more than 1.0 ppm of hexavalent chromium. The present Public Health Service limit on chromium is 0.05 ppm. There is serious doubt whether this low limit can be met with future industrial expansion and greater doubt whether the cost involved in meeting such a standard is justified. Experimental work on the toxicity of chromium is urgently needed.

Cadmium is also a cumulative poison. There is a possibility of cadmium in water from industrial wastes or cadium coated pipes, but no data on its effect on humans are available. Relatively large doses (31 to 50 ppm) in water supply affected rats by stunting their growth and rendering them anemic (32).

The everpresent possibility of intensive chemical dose by cross connection of an industrial water supply to a potable water supply must be considered. Wustenberg (36) recently reported an instance in Germany where such a cross connection premitted a river water containing carbon sludge to enter the main distribution system. Poisoning of young children and infants, in some instances fatal, resulted.

Another possible avenue for the poisoning of a water supply is through increased use of insecticides, especially when applied intensively over an area. An instance was reported (37) where the seasonal application of insecticides for boll weevil control resulted in complete fish kill in a stream. Where such waters are used for water supply, and complete treatment is not provided, it is conceivable that some of the poisons might be carried through to the consumer.

The concentration of twenty-eight trace metals in surface, ground and sea waters is given by Kehoe, Cholak, and Largent (38).

Methemoglobinemia

Since Comly (39) in 1945 traced the death of two infants in Iowa to the nitrate content of their water supply, some 262 cases and 29 deaths have been reported from 14 states (40). The disease, methemoglobinemia, is characterized by cyanosis, giving to the infants involved the label "blue babies." It is caused by reduction of nitrates in the body to nitrites. The nitrites react with the hemoglobin in the blood impairing its oxygen carrying capacity. This reduction does not take place in older children or adults. The nitrate-nitrogen content of waters held responsible has ranged from about 10 to 1000 ppm.

Nitrates in water have always been an indicator of pollution and had been routinely reported until better measures of pollution measurement were developed. However, many instances of high nitrate content in well waters have not been associated with identifiable pollution. Although most high nitrate waters originate in shallow rural wells, deep wells also have been found to be high in nitrates.

Most cases have been reported from the middle west, with 119 cases and 14 deaths reported in two and one-half years in Minnesota alone, with 90% of

the cases in children under 2 months of age (41). Naturally, dry and evaporated milk formulas are most dangerous, and boiling does not help, because it only concentrates the nitrate.

There are many more nitrate-bearing waters than cases of methemoglobinemia would indicate. In Texas, of 20,000 nitrate determinations, 3000 showed more than 20 ppm. Public supplies of 27 Texas towns and cities contained more than 50 ppm. Most of this high nitrate was found in wells less than 200 feet deep and principally in water drawn from Late Tertiary or Quaternary formations. However, the water was drawn from all types of rock, unrelated to rainfall, geography or cultivation (42).

It is not at all understood why there has been no difficulty from many of these nitrate bearing waters. The disease is not reportable and as Walton (43) points out it may be that many more cases, subclinical in nature, occur than are reported to physicians or health departments. Much work is needed in this area.

Sodium

Of all the cations likely to be found in water, sodium had been considered one of the least objectionable. Normally about 5 grams of salt are required daily, per capita, while the average intake is 10-15 grams daily (44). In healthy individuals, no harm results from excess salt intake. However, in the cardiovascular-renal diseases, which include arteriosclerosis, hypertension, and nephritis, diets low in sodium assist in relieving the edema which is symptomatic of these diseases. A guide for patients on low-sodium diets, "Planning Low Sodium Meals," issued by the Newton, Mass., Health Department (45) prescribes three levels of low-sodium diets: 200 mg, 400 mg, and 800 mg of sodium daily. The first is said to be useful for patients with hypertension and the second for patients with congestive failure.

These cardiac diseases are the leading causes of death today and when such low diets are prescribed the sodium content of drinking water may become a factor to consider. In most surface supplies the sodium content will be low, and need be given little consideration. In Durham, N. C. for example, the sodium content is about 4 ppm, which will, in $1\frac{1}{2}$ liters of water consumed daily, amount to only 6 mg.

In certain well waters, however, the sodium content can be quite high. Galveston, Texas and Galesburg, Illinois have waters containing more than 300 ppm of sodium. Consumption of these waters will, without any food intake at all, exceed the allowable limit in the two more strict diets. Many small well supplies in the southwestern part of the U. S. have even higher concentrations of sodium. It is interesting to note that an addendum to the pamphlet Planning Low Sodium Meals warns against the use of softened waters. This warning, of course, should have been qualified to permit the use of lime-softened waters.

The sodium content of waters in the larger cities has been well established. Determination of the sodium content of waters in 159 cities representing 28 per cent of the population in the U. S. has been made by the flame photometer (46). Routine analysis of well waters by the U. S. Geological Survey, however, generally lumps sodium and potassium together. Potassium is of no interest. It would therefore be encumbent upon water works operators, state health departments and other responsible officials to establish as soon as possible the sodium content of their waters so that physicians might guide their patients in its use.

Derby (32a) points out that the lithium which had been exploited in medical

spring waters is now found harmful in quantities used for salt-substitutes in low sodium diets. Lithium chloride and potassium chloride have both been found to be toxic to patients on low sodium diets and the Food and Drug Adminstration has classified these salts as drugs.

Radioactivity

The ever wider adoption of radioactive processes in industry, medicine, research and soon in power production will inevitably lead to increasing levels of radioactivity in waste waters and thence in water supplies. The sanitary engineer will have to become familiar with this newly important characteristic of waters. He will have to determine the concentration of radioactive substances in wastes and in waters to be used for various purposes. If these concentrations exceed permissible limits he will then have the problem of bringing the radioactivity within these limits either at the source or at the waste or water treatment plant.

As Morgan (47) points out, radioisotopes present much greater hazards when they are ingested than when they are present only externally, for the following reasons:

1. They irradiate the body continuously until they are eliminated.
2. The biological half-life is very long for some radioisotopes and in most cases it is difficult - if not impossible - to increase appreciably the rate of elimination of these isotopes from the body.
3. The sources of radioactivity inside the body are in intimate contact with the body tissue. This enables alpha and low-energy beta radiations, which do not present an external hazard because of their limited range, to reach sensitive tissue inside the body.
4. It is difficult to measure the amount and distribution of a radioisotope in the body so that it is usually impossible to assess the hazard accurately.

Damage from radioactive emissions is somewhat similar in nature to that from cumulative poisons, in that in addition to level of radioactivity, the duration of exposure is important. There are important differences however. Radiation damage to man increases with total accumulation of exposure. For example, small over-exposures, whether continous or intermittent, may add up to enough dosage to cause physiological damage, although the effects might not be recognized for a considerable period as having resulted from exposure to radioactivity.

In general, greater damage results from short period, high intensity radiation than from an equal amount of radiation exposure spread over a longer period of time. Then, there are different types of radiation which have different penetrating and ionizing powers: alpha radiation, although less penetrating, is often more hazardous than beta or gamma because of its high ionizing power in tissue. The source of the radiation is extremely important. Some radioisotopes have a high energy of disintergration and are particularly damaging, while others have low energy and are less hazardous. The genetic mechanism of cells is easily damaged and it is reported that the amount of genetic damage caused by a given dose of radiation is the same whether the dose is given in a single short exposure or intermittently over a long period of time (48).

The problem of setting limits for maximum permissible concentrations of radioactivity therefore becomes most complex. Different radioisotopes have different permissible concentrations. There is the problem of distinguishing between the various isotopes in water or waste. It is obviously impractical in a water or sewage treatment plant to determine routinely the radioactivity

from each of the isotopes that might be present, and so an overall permissible concentration level has been established for drinking water based on the most damaging isotopes. The Subcommittee on Internal Dose of the National Committee on Radiation Protection has recommended provisionally that the maximum permissible level of radioactivity in water be $1 \times 10^{-}$ microcuries per milliliter in addition to the radioactivity present naturally (49). This value is believed to be safe for exposure to any of the radioisotopes for periods of a few months.

Whether it will be economically feasible to meet exacting standards under the pressure of intensive exploitation of radioisotopes and nuclear energy remains to be seen. Failure to develop economical methods for controlling radioactive waste discharges may well hinder the exploitation of this new tool.

Ruchhoft and Setter (50) have shown data based on the 1950 use of radioisotopes in our large cities which indicate that the level of 1×10^{-7} microcuries per milliliter in the sewage has very nearly been reached. In many communities, with the expansion in the use of radioisotopes, it may be difficult to maintain waters within this permissible limit. However, it may be unnecessary to meet this limit if the sources of radioactivity are known. Handbook No. 52 of the National Bureau of Standards (49) lists substantially higher maximum permissible concentrations for most of the radioisotopes which are likely to be of interest. For example, the MPC for Iodine-131, an isotope widely used in medical work, is given as 3×10^{-5} microcuries per milliliter. Incidentally this value is only one tenth of the permissible limit for I-131 as shown by Ruchhoft and Setter (50).

The weakness in setting up any single standard for radioactivity may be demonstrated by analogy with chemical poisons, where it is obvious that a limit of 0.05 ppm for all metals based on that for lead would be unreasonable for the other metals which are less toxic. This problem does not arise in chemical poisons because the concentrations of the various metals can be readily determined. With the standard radioactive monitoring devices that might be used for water, it is not feasible to distinguish between low level emissions from a toxic high-energy isotope and a non-toxic, low-energy isotope. Part of the solution may lie in continous close control of the distribution of radioisotopes and include supervision of radioactive discharges at their source.

It is apparent that, if disposal of radioactive wastes is to be reasonably administered, the considerable research now being carried on to guide the establishment of permissible concentrations must be continued. The problem of limits for short-time high-intensity exposures in drinking water is even more confused. Uncertainty is evidenced in the American Water Works Association Task Group Report and the criticism thereof by Setter (51). The disparity in recommended tolerance levels for 30-day exposure to beta radiation is 300-fold.

Permissible limits have not yet been established for surface waters to be used for bathing, for sustaining fish life, for irrigation and for industrial water supplies. This problem is complicated by the concentrating effect of slimes and algae and by the transfer of radioactivity to cows, fish, fruits and vegetables.

In any case it is apparent that the economical reduction of radioactivity to tolerable levels will depend upon the efficacy of water and waste treatment processes. Numerous investigations in this area are under way, and from preliminary reports in appears that the standard complete treatment processes for water and sewage are effective in removing some radioactive contaminants.

Removal of radioactivity by water or sewage treatment processes does not

entirely solve the problem. Ruchhoft, Gorman and Christenson (52), in pilot plant tests on the chemical coagulation of radioactive isotopes, found that after dewatering by filtration, the sludge cake had to be put into oil barrels and stored in the "contaminated storage" area. For each million gallons of sewage treated, 2000 gallons of sludge would have to be stored to permit decay of the radioactivity.

Scott (53) shows calculations that indicate that if excreta from 50 patients being treated with radioisotopes are discharged to the sewers of San Francisco, the radioactivity on the sludge cake produced at the sewage treatment works would be a hazard to health. Because of the concern created by Scott's paper, Ruchhoft and Feitelberg (54) reviewed the situation in San Francisco. On the basis of (a) dilution with the sewage flowing to the Richmond-Sunset plant, (b) the time for decay provided by 38 days of digestion (amounting to four half-lives for Iodine-131), (c) the unlikelihood of discharging the high activity promised by Scott, and (d) the low transfer of radioactivity from sewage to sludge likely to be experienced in primary treatment provided at the Richmond-Sunset plant, they conclude that there is not likely to be hazard from the sludge at the plant.

However, sanitary engineers should still be greatly concerned with this problem, which may be aggravated by an increasing contribution of radioactive wastes from research institutions and industry as well as medical establishments; by the use of more diverse and longer-lived isotopes; by the discharge of these wastes into sewerage systems of smaller communities than San Francisco, which will offer much less dilution; by a greater transfer of radioactivity from sewage to sludge in the activated sludge process; by the quick-drying of fresh sludge which eliminates the long digestion period and offers no time for decay; and by the difficulties of supervising waste disposal practices from non-AEC users of radioactive isotopes.

Furthermore, sanitary engineers engaged in the investigation, design and operation of sewage and water works will have to take into consideration the handling of radioactive contaminants in sewage and water, and will have to become familiar with the theory, techniques and equipment involved.

Promotion of Well Being

If he accepts the modern concept of health, as enunciated in the preamble to the constitution of the World Health Organization, the sanitary engineer faces many new challenges. This concept is stated as follows:

> "Health is a state of complete physical, mental and social well being, and not merely the absence of disease or infirmity."

Acceptance of this wider, more postive concept of health without doubt broadens the horizon of activity for the sanitary engineer engaged in water and sewage work. Within his purview now come activities in fluoridation, air conditioning and community development. And of paramount importance is his obligation to make available an abundant supply of water so as not to restrict its use for any beneficial purpose.

Fluoridation

The nationwide acceptance of and demand for fluoridation of water supplies low in fluoride for the promotion of dental health is perhaps the most outstanding demonstration of the acceptance by the people of the new concept of health.

Extensive epidemiological studies made in the early years of the last de-

cade indicated that there is an inverse relationship between the prevalence of dental caries and fluoride in the water supply, if the fluoride is ingested during the years of tooth development. It was found that when there is about one ppm of naturally occurring fluoride in the water supply some six times as many children show no caries development and the caries experience rate is reduced about 60 per cent as when the water supply contains no fluoride. Approximately 4 million people are now consuming water containing optimum concentrations of naturally-occurring fluorides.

Well controlled studies were initiated, and are still in progress, to determine whether the addition of about one ppm of fluoride to a fluoride-free public water supply would have beneficial effects similar to those experienced with waters naturally containing fluoride. The first of these, beginning January 1945 at Grand Rapids, Michigan, has shown that in the five-to-seven-year age group, the incidence of caries experience after almost 7 years is practically the same as that in children in the same age groups in Aurora, Illinois, where the natural fluoride content of the water supply is 1.2 ppm (55). Examination of permanent teeth revealed a 66.6 per cent reduction in caries in 6-year old children in Grand Rapids whereas there was virtually no change in Muskegon, Michigan, the city used as a control. Before floridation was begun at Grand Rapids, the caries experience was about the same as in Muskegon.

In May 1945, the addition of sodium fluoride to bring the fluoride content up to 1.1 ppm was begun in Newburgh, New York, while the water supply to the neighboring city of Kingston was kept fluoride-free. A preliminary report (56) of this controlled test indicated that after three years of fluoridation, the caries experience, including teeth decayed, missing or filled, in Newburgh children (6-12 yrs.) decreased 32.5 per cent while it remained unchanged in Kingston.

In Brantford, Ontario, where fluoridation was begun in June, 1945, at the end of five years it was shown that the teeth decayed, missing and filled of 5, 6 and 7 year old children declined 54, 43 and 45% respectively. Children in school with perfect teeth increased from 5.18 to 15.63% (57).

As the period of fluoridation increases, it is expected that the benefits will approach those reported for cities using waters containing naturally occurring fluoride.

Thorough studies have been made of the physiological effects of fluoride on the body. McClure (58) has reported that the body has an efficient mechanism for the elimination of fluorine. He reports that 90% of the fluoride ingested (3-4 mg. per day) is eliminated in the urine, sweat and feces. He reports no difference in height, weight, and bone fracture experience among large numbers of boys and men examined for selective service from fluoride and fluoride-free areas. Cox and Hodge (59) also report no toxic side effects from fluorides. They report some possible benefits from fluorides in water in relation to hearing. On the basis of the examination of 130,000 children, 4.9 per cent hearing defects were found in children from low-fluoride areas, while only 2.8 per cent in children from fluoride areas.

Cox and Ast (27) have shown that the toxicity level for a single dose is so high that to have effect, 0.25 gms. of sodium fluoride would need to be present in an 8-oz glass of water, or a rate of chemical dosage of 4 tons per million gallons.

Water is ideally suited as a vehicle for the administration of beneficial substances to the entire population of an area. No other dietary constituent is so nearly the same for everyone. In the past, except for a short period

when iodine was added to water as a goiter preventive, treatment works have been devoted only to removing or neutralizing harmful substances. All indications are that the public will soon demand fluoridation of all waters low in fluorides. The time may be envisaged when water will be used to carry other health-promoting substances to entire populations.

Air Conditioning

The expansion in the use of air conditioing devices, particularly in industry and in public buildings, has no doubt had a marked effect on the efficiency and well being of personnel employed in these buildings. There are few data concerning the influence of air conditioning on the health of persons employed in air-conditioned buildings. Such studies as have been made have been disappointing - respiratory infections have persisted among those working in air-conditioned buildings. However, these studies have had little validity because only eight hours of the day were controlled and the effect of the remaining uncontrolled sixteen hours may well have screened the effect of the air-conditioning.

Keeton (60) has shown that enviromental atmospheric conditions play an important part in the health of many people. When the environment is changed from that described as "comfortable" to that described as "hot moist," certain body changes occur to facilitate disposal of body heat:

a. Peripheral blood flow is increased.
b. The cardiac discharge increases 50 to 60 per cent.
c. The heart rate is increased.
d. When the heart fails to increase the blood flow, fever results.
e. Oxygen consumption rises.

The net result of the uncomfortable environment is the development of a stress which throws additional work on the cariovascular system. It is generally recognized that patients with heart disease tolerate hot moist weather poorly. Heat waves may be followed by a wave of cardiac deaths. The importance of cardiovascular diseases today places air-conditioning for many at the level of necessity rather than luxury.

Most large air-conditioning units depend upon water supply for their operation, yet Bean (61) reports that 21 communities with a population of 18.5 million have restrictions on the use of water for refrigeration purposes, while 12 additional communities with a population of 5.75 million have restrictions on the use of sewers for air conditioning cooling waters. Fifteen other communities, serving 7.25 million people, have reported critical water supply or sewerage capacity problems. Thus, about one-third of all the consumers using public water supplies do not have free access to water for air conditioning. Thus, the sufficiency of available water and adequacy of disposal systems may be vitally important to the health and well being of a community.

Community Environment

In 1930, several articles in Water Works Engineering pointed out ways of encouraging consumption of water. These included garden hose sprays for children, portable wading pools and the development of beautiful lawns by sprinkling. It should be noted that these are all summer-time activities, when recent water shortages have been most severe. The failure of water supplies to keep up with and anticipate requirements has led to programs for diminished use, particularly in the curtailment of lawn sprinkling.

It may be impossible to evaluate quantitatively the importance to "well-

being' of the ability to create in a community a pleasant and wholesome environment. We might, however, readily imagine that between two communities, one with lawns burned each summer and no parks, and the other with healthy lawns, ample greenery and public parks, one of them would decidedly be a more desirable and healthful place in which to live. Just such considerations have already affected industry's choice of plant sites. Those who have been responsible for the creation of new communities in connection with industrial developments in many parts of the world have recognized the need for providing water, even at great expense, for maintaining lawns. In one development in South America, for example, about ten times as much water is provided per capita for lawn sprinkling as for domestic use. Industry has found such investments to be economical in that they provide a much better labor supply by avoiding excessive labor turnover with concommitant expenses in training and overhead.

In its thirty "Basic Principles of Healthful Housing" (62) the American Public Health Association included a number that depend upon the availability of adequate and safe water supply and satisfactory waste disposal:

(a) "Provision of facilities for maintenance of cleanliness of dwelling and person.

(b) "Provision of water supply of safe sanitary quality, available to the dwelling.

(c) " Protection of water supply against pollution within dwelling.

(d) "Provision of toilet facilities.

(e) "Provision of adequate space for exercise and for play of children."

The last principle deserves special mention. Early in this paper, the high suicide and homicide rates were pointed out. These, in great measure, are products of social and mental disease. While it may be difficult to relate mental health and well-being specifically to housing and recreational facilities, and much less to adequate water supply and waste disposal, some statistical studies may be useful. Britten (63), for example, has pointed out in analysis of data reported by Hadley (64), that of 5800 examinations given to young men on induction into the army, rejection rates for personality disorders were $1\frac{1}{2}$ times as great for men from slum areas in Washington, D. C. as from areas with good housing. Hyde and Kingsley (65) have shown that in examinations of 60,000 selectees, the total incidence of mental disorders, rate of mental deficiency and rate of psychopathic personality all increased from best to poorest communities.

As Pond (66) points out, substandard community environment probably never is the only factor contributing to the detriment of health. Associated with poor housing will be poverty, crowding, illiteracy, poor nutrition, and delinquency. On the other hand it may be appreciated that certain community problems, such as juvenile delinquency, may be related directly to the absence of adequate recreational facilities. New industry, and communities themselves, by indiscriminate discharge of wastes, may destroy the only available recreational facilities such as swimming or fishing areas. While avowedly, the economic importance of these recreational facilities may be small, community and industry should cooperate in securing either adequate treatment of wastes, or if that be too costly, replacement of the despoiled recreational areas with others.

Here again, in evaluating the effect of wastes on bathing waters, sanitary engineers have a responsibility. A nationwide survey conducted by the Joint Committee on Bathing Places of the Conference of State Sanitary Engineers

and the Engineering Section of the American Public Health Association (67) revealed"..... surprisingly little reliable data to indict bathing places in the spread of diseases." As pointed out by Stevenson and Woolsey (68), in preface to a study of the relation between bathing water quality and disease, standards for natural bathing waters are not based upon positive information on illnesses which may be attributable to water quality. This study, based upon investigation of 800 families using each of two Lake Michigan bathing areas in Chicago, indicated that bathing in these waters does not produce significant illness which can be attributable to water quality.

Subsequent studies, reported by Stevenson (69), on the Ohio River at Dayton, Kentucky and in Long Island Sound at New Rochelle and Mamaroneck, New York led to the same conclusions. He did report two instances where a specific correlation did appear to exist between illness and poor bacterial quality. However, the number of cases involved was small.

Criteria and standards have been established on the basis of expediency. Enforcement of such standards, without substantiating data in support of the standards, may properly be open to challenge, especially where considerable cost in the institution of remedial measures is involved. Stevenson (69) has already suggested relaxation of present standards for bathing waters.

The cost of treatment of municipal waters and wastes and industrial waters and wastes inevitably must be met by all the people. An unreasonable cost is then unreasonable not only for the offending party, but for all. Sanitary engineers, in concert with the epidemiologist, must get data on the transmission of diseases through contaminated bathing waters.

Adequacy of Water Supplies

The urgency of water supply sufficiency need not be belabored. Yet there is no insufficiency of water. We, as the Ancient Mariner, are faced with

"Water, water, everywhere
Nor any drop to drink."

The water is present, but often unavailable because it is in the sea, needing to be desalted, or it is deep in the ground, needing to be demineralized, or because it is high in the atmosphere, needing to be precipitated, or it is in a polluted river, needing to be made potable, or it is in a flood, needing to be stored.

Each of these processes is receiving increasing attention by the sanitary engineering profession because the need for water in many areas exceeds the available usable supply.

There is no question but that"a drop to drink" can be found in each of these sources, but the cost of the drop may frequently be so high as to place the water outside the reach of most communities. Moore (70), in his survey of methods for desalting saline waters indicates that, depending upon the salinity and the method used, the cost of producing a potable water varies from $400 to $6000 per million gallons, more than 10 to 150 times greater than the cost of purifying fresh water. He suggests more investigation into methods of vapor compression, on exchange and solar distillation.

Extraction of water from the atmosphere in arid areas by rainfall stimulation is finding continuously more extensive application, and is a development of importance to sanitary engineers.

The restoration of polluted waters to usefulness, and the harnessing of flood waters to serve in periods of drouth, are not new problems for the sanitary engineers, but they are no less problems for being time-honored.

Service to the health of communities requires economical and feasible solutions to these problems.

CONCLUSION

Despite laudable achievements, sanitary engineers and allied scientists concerned with water supply and waste disposal works still face many challenging problems. These include:

1) The elimination of typhoid fever as a water-borne disease by promotion of water treatment for all municipal, camp and institutional supplies.
2) The exercise and promotion of eternal vigilance to prevent explosive water-transmitted disease outbreaks.
3) Better evaluation of the true incidence of certain water-borne diseases, especially infectious hepatitis.
4) Investigation into the effect of water and sewage treatment processes on the viruses which may be transmitted in water.
5) Investigation into the effect on humans of the compounds from industry finding their way into streams.
6) The development of methods for removing excess fluorides from water.
7) Investigation into the relationship between nitrate nitrogen in water and methemoglobinemia.
8) Determination of the sodium content of all potable water supplies.
9) Establishment of safe levels of radioactivity in water, sewage and sludges. Development of methods for protecting workers in water and sewage works plants, and for measuring and removing radioactivity.
10) Promotion of dental health by assisting the dental profession in extending fluoridation.
11) Development of adequate supplies of water so that it will be available in the quantities needed for air conditioning, lawn sprinkling, etc.
12) Evaluation of importance of polluted bathing waters in the spread of disease so that criteria for such waters will be sound.
13) Utilization and development of water works and waste disposal systems for the improvement of community environments.

> "Happy is the man who works in a noble element.....
>
> "You are engaged in beneficent endeavor to bring into every home an abundant supply of pure water: to see that the industries and acts of men are stimulated by an ample, inexpensive and convenient supply of the same invaluable fluid: to insure our cities and towns from destruction by ruinous conflagrations...: to adorn....with beautiful fountains, the grateful reminders of those natural springs and cascades, which, wherever they abound, cause their whereabouts to be celebrated in story and song.....
>
> "The work in which you are engaged is of inestimable value. It reduces the death rate. It promotes health. It induces cleanliness. It enhances comfort. It humanizes. It saves measureless toil..."

Thus spoke Reverend D. N. Beach to a group of sanitary engineers in 1888 (71). Our goals should be no less inclusive today.

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